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Contract No. W-35-058 eng. 71

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INSTRUMENT DEPARTMENT

J. R. Brand, Supt.-Instruments

DECLASSIFIED Per Letter Instructions Of AEC 4-13-54

MS for M. T. Bray 4/21/54 SUPERVISOR LABORATORY RECORDS ORNL

THE MONITRON,

AN AREA MONITORING INSTRUMENT

8/15/45

* * *

Experimental Work By: C. O. Ballou
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Submitted By: C. O. Ballou

Approved By: G. S. Pawlicki

This report covers work between periods

October 1944 - May - 1945

* * *

Received: 9/8/45 Issued: 9/11/45

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ABSTRACT

An instrument for the measurement and recording of radiation with an alarm system to indicate certain limits of radiation was required. Further, the instrument was to be free from severe fluctuations or instability.

An instrument capable of being accurately calibrated regardless of normal differences in input resistors and meeting outlined requirements has been developed and proven by several months operation.

The salient feature of the instrument, is that amplification is accomplished thru an AC amplifier instead of a DC amplifier. The AC component, which is amplified, is derived thru modulating the plates of a pair of Victoreen 124 tubes. Amplification of the AC component is accomplished by means of a conventional audio amplifier which is free from drift and the instability of DC amplifiers.

In general, the instrument involves no new principles of operation, but does bring together in one unit a number of ideas which contribute to improved performance and stability.

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MONITRON

I

Introduction

A. Requirements

With the introduction of a new process having severe health hazards, radiation measuring equipment having specific characteristics were required.

After due consideration, the following features were deemed necessary for proper radiation measurement in 706-D:

1. Number and Location

   A minimum of eight instruments located at various points in the building shall be required.

2. Sensitivity

   The instruments shall have two ranges: one reading 25 mr/hr full-scale and the second reading 125 mr/hr full-scale. Change of ranges shall be accomplished by means of a switch manually operated at the instrument.

3. Calibration

   The instruments shall be capable of exact calibration on one range. The error in calibration on the other range shall be contingent upon the selection of proper ratio input resistors. (NOTE: The instruments, as finally designed, were capable of exact calibration on both ranges.)

4. Recording

   To conserve recorders multipoint Leeds & Northrup recorders shall be used. Two eight-point recorders shall be connected in such a manner that the radiation measuring point will record radiation and the unused range shall return the recorder to zero. Two points are thus available for each instrument and shall print as per the following schedule:

	INSTRUMENT "A"	INSTRUMENT "B"	INSTRUMENT "C"	INSTRUMENT "D"
25 mr/hr range	Pt. 1	Pt. 3	Pt. 5	Pt. 7
125 mr/hr range	Pt. 2	Pt. 4	Pt. 6	Pt. 8

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Printing colors shall be arranged such that each recorder will print both the high and low range of each instrument in the same color, and each individual instrument shall have a distinctive color.

5. Signal System

a. When the instrument is operating on the 25 mr/hr range, an alarm shall trip at $12\frac{1}{2}$ mr/hr. Tripping of this alarm will initiate the following signal system:

(1) Sound a buzzer located at or near the instrument

(2) Light a red signal lamp to be located on the instrument panel.

(3) Light a red signal lamp on the recorder panel. Separate signal lamps, properly designated, shall be required for each instrument connected to the Leeds & Northrup Recorder.

b. When the instrument is switched to the 125 mr/hr range, three warning lamps shall be turned on. These lamps shall be yellow or amber in color and located as follows:

(1) On the instrument panel.

(2) A 100 watt lamp located above the instrument.

(3) On the recorder panel. Separate signal lamps as outlined under A-3 shall be required. No alarm system shall be required on this range.

B. Previous Practice

A review of radiation instrumentation brought forth the fact that no instruments available or known would accomplish the outlined requirements. It must be confessed that several of the requirements were optimistically written around some development work initiated in November 1944 utilizing modulation.

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II

Description of New Instrument

A. Electronic Circuit

With the operating and maintenance experience gained at Clinton Laboratories, the writer felt that much could be gained if the amplifier and power supply of a micro-microammeter could be simplified.

Preliminary work was based upon applying alternating currents to the various elements of an electrometer tube and amplifying the increments of alternating current due to changes in grid potential by means of an audio amplifier. 959, V-32 and V-124 tubes were investigated with considerable promise. The V-124 tube, due to higher and more uniform grid to other element resistance, was finally selected and efforts were concentrated upon building a modulated amplifier to meet preliminary specification.

The final circuit given on the appended circuit diagram was the result of this work. Briefly, the circuit is as follows:

1. Conventional input practice is followed with the addition of a 50 micro-micro-farad condenser from grid to ground. This condenser removes a small AC component from the input grid which is picked up due to tube and stray capacitances. This practice is a hangover from early work and considerable controversy exists over its necessity. It appears entirely feasible that it is not required.

2. The 10,000 ohm potentiometer in the space charge grid supply circuit adjusts the plate currents of the input tube and its balance tube, so as to obtain convenient zero setting with the 50,000 ohm potentiometer in the plate circuit. The 10,000 ohm potentiometer is placed on the back side of the tube compartment and is adjusted only after tube replacement. The 50,000 ohm potentiometer is on the front panel and is used for zero adjusting.

3. 2.5 volts at 60 c.p.s. is used for modulating and is obtained from the power supply transformer which in turn must be supplied from a constant voltage source.

4. Unbalancing of the input pair is accomplished through different value plate load resistors. The necessity for this will be covered in paragraph 7.

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5. The input pair and the amplifier handle the modulation in push-push, not push-pull. That is: the phase relationship is the same or approximately so on both sides of the amplifier. Early work indicated that better balancing could be obtained by push-push. However, it appears that either method would be satisfactory. It should be pointed out that a push-push amplifier with un-bypassed cathode resistors is highly degenerative, which is desirable from the standpoint of tube replacement.

6. The audio amplifier is quite conventional with the exception of the output circuit. The 6K6 screen grids, when supplied directly from the B+ bus, introduced particularly heavy hum back into the B supply. Further, this hum component was approximately 90° out of phase with the signal at the 6K6 plates. This produced a complex wave form in the output transformer and gave a calibration which was badly curved. A decoupling resistor and 20 mfd condenser in the screen circuit reduced this effect to such an extent that it was possible by tuning the output transformer with approximately 0.1 mfd capacity to obtain sine wave output from the amplifier.

7. The output transformer, which is connected for push-pull operation, adds the two signals in opposition and in the first unit an effort was made to obtain complete cancelation of the two in-phase components. While it was possible to obtain satisfactory operation on one unit with such operation, it became apparent that such a method was not practical when the remaining seven units were put on test. Consequently, the circuit was changed to throw the modulating circuit out of balance by means of different plate load resistors and then to correct for the high reading on the milliammeter. A bucking current obtained from the 75 volt regulated supply and controlled by a 150,000 ohm resistance gave the required correction. This current amounting to approximately 500 microamperes, depending upon the sensitivity adjustments, was introduced into the milliammeter to suppress the initial reading.

8. Development of modulation theory applied to this instrument is given in appendix II.

B. <u>Recording Circuit</u>

Connected in the metering circuit are two 21 ohm hand wound and adjusted manganin resistors. Shunting each of these resistors is a 500 ohm potentiometer with which the parallel network can be adjusted to precisely 20 millivolts drop with a full-scale meter reading. Each

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of the two networks is paralleled with a 50 mfd low voltage electrolytic condenser to reduce the rectified AC component appearing across the Micromax galvanometer.

Two such networks are required to properly operate the Micromax. One of the two networks is connected to the amplifier circuit by means of the range selector switch and the I.R. drop across the selected network operates the Micromax. The other network is isolated from the amplifier by the selector switch, but this network remains connected to the Micromax point selecting switch and when the Micromax connects itself to the isolated resistor, the recorder returns to zero. The recorder thus alternately prints up-scale and zeroes when all amplifiers are working on the same range. This results in a particularly legible record.

A common lead is used to connect the two circuits to the Micromax as some of the amplifiers are located about 200 feet from the recorder. The same is also true of the alarm circuit, and has resulted in appreciable economies in the installation of the equipment.

C. Alarm Circuit

In view of the fact that the amber lamp circuit draws over 100 watts, the use of unregulated voltage appeared attractive, as voltage regulating transformers would be economically wasteful to supply the lamp circuit for the short time during which it would be operative.

In use it was anticipated, and has worked surprisingly well, that the instruments would operate on the 25 mr/hr range most of the time. When the radiation exceeded $12\frac{1}{2}$ mr/hr, as evidenced by the buzzer and red signal lamps, the instruments would be manually switched to the 125 mr/hr range. The amber lights would thus call attention to the fact that radiation was at or above the 8 hour tolerance.

When the selector switch is on the 25 mr/hr range, the alarm system is actuated by a relay. The closing of the relay is adjusted to half-scale meter reading by means of the 10,000 ohm potentiometer in the cathode bleeding circuit of the 6J5 tube. To reduce the ratio of pull-in to drop-out current in the relay, one of the two associated relay micro switches is so connected that when the relay is in the open position the entire plate current of the 6J5 energizes the relay coil. When the relay closes, enough of the tube plate current is diverted through a 10,000 ohm resistor to energize the relay to threshold drop-out current. In practice it has been found that different spring tensions on the relay armature require adjustment of this resistor.

An R.C. filter has been used in the grid circuit of the relay tube to prevent 60 cycle chattering of the relay.

D. Chamber

Due to leakage, and electrostatic potentials generated by the movement of cables, it was decided to mount the chambers directly on the amplifier and thus avoid the troubles associated with cable connected chambers. Chamber dimensions were made such that when the chamber was screwed onto the input connector its base exerted light pressure on the

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top of the cabinet. This construction resulted in a rigid structure, easy servicing and a one unit radiation instrument.

The volume of the chamber was computed to give 1×10^{-11} amperes (more precisely $.973 \times 10^{11}$) at 25 mr/hr. Thus with a 10^{11} ohms input resistor the voltage sensitivity required would be approximately one volt. With 2×10^{10} ohms input resistance for the 125 mr/hr range the voltage sensitivity would remain the same. Input resistors were selected to obtain the outlined input characteristics, and calibration of the meter for definite levels of radiation is obtained by adjustment of the 70,000 ohm potentiometers. Precise calibration of the instrument is thus possible with input resistors of commercial tolerance.

E. Recording Instruments

Standard 20 millivolt Leeds & Northrup multi-point recording galvanometers were used.

These instruments incorporate an eight position selector switch which is driven by a syncronous motor. The switch indexes every 57 seconds recording a complete area survey every seven minutes and 36 seconds.

As in all galvanometer instruments of this type, the external circuit must include a low resistance. If the external circuit is open, the galvanometer is undamped and swings violently when the clamping bar releases the galvanometer arm. This causes the printing mechanism to rove up and down scale, printing random and meaningless points.

To force zero readings on the unused amplifier position it was necessary to use two 20 millivolt dropping resistors in the amplifier and thru the input selector switch select the proper one for operating the Micromax. The remaining resistor supplied the required low resistance, with no potential across it, for returning the Micromax to the zero position.

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TEST DATA

The chambers associated with the Monitron were designed to give 1×10^{-11} amperes at 25 mr/hr. By using the chamber current and input resistor values, the voltage appearing across the input resistor can be computed. Thus, knowing the value of the input resistors, it is possible to adjust the instruments by means of the two 70,000 ohm potentiometers to the desired radiation levels.

The input resistors of four instruments were carefully measured with a General Radio Megohm Bridge and the voltage of the instruments adjusted to computed values. To check the validity of this adjustment, the instruments were check calibrated with a Ra-Be source.

The instruments failed to check on the radiation calibration and the calibrating potentiometers were adjusted to give full-scale meter readings at 25 and 125 mr/hr on the two ranges. One instrument was damaged during transportation to the calibrating area; so data was obtained on only three instruments.

After the instruments had been calibrated with the Ra-Be source the following measurements were made:

Instrument #1	25 mr/hr	125 mr/hr
Input resistance	4.7×10^{10} ohms	1.50×10^{10} ohms
Voltage sensitivity	0.767 volts	0.708 volts
Instrument #2		
Input resistance	5.5×10^{10} ohms	1.40×10^{10} ohms
Voltage sensitivity	0.745 volts	0.734 volts
Instrument #3		
Input resistance	7.0×10^{10} ohms	1.45×10^{10} ohms
Voltage sensitivity	0.746 volts	0.660 volts

Computing chamber current from the above data we get the following currents for the 25 mr/hr range:

Instrument #1	1.63×10^{-11} amperes
Instrument #2	1.35×10^{-11} amperes
Instrument #3	1.08×10^{-11} amperes

Obviously something was wrong. A check of chamber computations, radiation, voltage and resistor measurements gave no clues. An investigation covering several weeks of study and experiment was futile.

Several days before operations were to begin, the instruments were calibrated by means of radiation from a Ra-Be source and installed.

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After installation the cause of the erroneous results was uncovered and is discussed in the appendix under "Hi Resistance Technique".

After the change in measuring technique had been instigated, the following chamber currents were computed from radiation calibration:

	25 mr/hr	125 mr/hr
Instrument #1	0.935×10^{-11}	4.02×10^{-11}
Instrument #2	0.945×10^{-11}	4.45×10^{-11}
Instrument #3	1.03×10^{-11}	4.25×10^{-11}
Instrument #4	0.935×10^{-11}	3.82×10^{-11}
Instrument #5	1.08×10^{-11}	4.55×10^{-11}
Instrument #6	0.959×10^{-11}	4.34×10^{-11}
Instrument #7	0.925×10^{-11}	4.39×10^{-11}
Instrument #8	0.976×10^{-11}	4.09×10^{-11}

It will be observed that the 125 mr/hr chamber current computes about 20% low. This has been attributed to poor geometry of radiation in the calibration, as the source was rather close to the chamber. With the exception of Instrument #4 the results agree within the limits of techniques employed.

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DISCUSSION OF INDICATED IMPROVEMENTS

Inasmuch as the instruments have performed so satisfactorily, no immediate program has been considered for improvements. Neverthless, certain difficiencies are known and future instruments might incorporate several changes.

1. The instruments, when operating under present conditions, are amply stable. However, the stability could be further improved by using an oscillator for supplying the AC component for modulation. This oscillator should incorporate some form of automatic amplitude control. The amplitude of the modulating voltage is at present regulated with a Sola 125 V.A. regulating transformer. This results in a marked increase of stability over line operation and was selected because of extreme simplicity and reliability. The use of two voltage regulating transformers in tandem might be given consideration. The second transformer could be of the 110 to 2.5 volt type of 15 V.A. capacity. This transformer would be used only for supplying the modulating potential.

2. The present instruments are not linear in calibration; the deviation from linearity amounting to slightly over 5%. Further, it is not the same in all instruments. It appears to result from non-linear characteristics of the Victoreen 124 tubes. By restricting the grid voltage excursions, the linearity can be improved directly as the excursions are restricted.

   Feedback from the output circuit to the input grid would restrict the effective grid excursions and thus, correct the present non--linearity.

   Such a circuit, in addition to correcting for curvature, could also become a source of extreme trouble. The amplifier is unable to distinguish between a positive or negative signal applied to the input grid. Although the rectifier circuit is carrying buck-out current of approximately 500 microamperes, which corrects this trouble for metering purposes, it is possible for a strong negative signal applied to the input to cause inversion of feedback and produce regeneration. Due to this inversion, the meter would read beyond full-scale and under normal conditions never return. The possibility of a rectifier to block off a signal of improper polarity at the grid return might possibly solve the problem.

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"HIGH RESISTANCE TECHNIQUE"

Inconsistancies in high resistance measurements, when made with the General Radio Bridge and then compared to the condenser discharge method, had been noted for some time. However, these inconsistencies had not been too troublesome until the development of the Monitron.

It was anticipated that the Monitrons might present a service and maintenance problem inasmuch as consistent and accurate calibration was required. Failure of the instruments to show a consistent relationship between measured input characteristics and computed characteristics was cause for considerable alarm.

Two of the instruments were located adjacent to the ceiling. To measure the input resistors with the General Radio Bridge was almost impossible due to the bulk and weight of the Bridge. A small instrument, using Victoreen 32 tubes for a Voltmeter and a voltage divider similar to the "Ohms" circuit of a Voltohmyst, was devised to permit the resistor measurement of these two instruments.

When resistance measurements were made with this "Megohmeter", entirely different results were obtained than the measurements given by the General Radio Bridge.

Following are comparative measurements obtained on the previously mentioned three instruments with the Megohmeter and General Radio Bridge.

	G. R. Bridge	Megohmeter
Instrument #1	47,000 megs	70,000 megs
Instrument #2	55,000 megs	70,000 megs
Instrument #3	70,000 megs	70,000 megs

Further investigation disclosed that the application of 90 volts to the resistors by the General Radio Bridge permanently changed their value. It has frequently been noted at Clinton Laboratories that Victoreen resistors measured appreciably less than the indicated value. However, the Megohmeter which applied a miximum of $1\frac{1}{2}$ volts to the resistor, showed that even though the resistor had changed value permanently as a result of the G. R. Bridge measurement, the value might or might not be that which the General Radio Bridge indicated.

A study of 96 resistors made by Victoreen, S. S. White and I.R.C. led to the following conclusions:

VICTOREEN

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1. Victoreen resistors are permanently changed in value by the application of as little as 5 volts. Increased potentials continue to produce a reduction in resistance. No resistor investigated

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changed after the application of 70 volts, although several resistors reached an "end point" of value with the application of 25 volts. Several resistors were subjected to 1500 volts with no change in resistance beyond that experienced with 70 volts.

2. Some, but not all, Victoreen resistors have a voltage coefficient. This is shown by the fact that some resistors measure one value when measured on an instrument that applies 90 volts and another value when measured with $1\frac{1}{2}$ volts applied to the resistor.

3. Victoreen resistors, within our ability to measure, show no appreciable temperature coefficient.

<u>S. E. WHITE (Dentalab resistors)</u>

1. Dentalab resistors have no change in resistance value when subjected to various potentials up to 1500 volts.

2. Dentalab resistors measure the same at low and high applied voltages, so do not have appreciable voltage coefficient.

3. Dentalab resistors appear to have a very high temperature coefficient. Some discussion from the practical use of these resistors centers around the fact that they may be thermo-electric. In either case, the use of these resistors in variable ambients has given rise to variable results.

<u>I.R.C.</u>

1. I.R.C. resistors are free from all the defects noted in Victoreen and Dentalab resistors. In addition, these resistors check their indicated values within very close limits, except the 10^{11} resistors.

This investigation of resistor characteristics has brought to light many factors which have at times produced very puzzling results. We feel that a great deal has been added to the "know how" of high resistance technique as applied to micro-microammeter work.

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APPENDIX II

Amplitude modulation in the Monitron is achieved thru the use of the curvature of the transfer characteristics. This is similar to that used in the van der Bijl modulator.

The characteristics of a triode can be approximately represented by the function $i_b = A(E_b + uE_g)^n$

i_b = plate current

E_b = plate voltage

E_g = grid voltage

u = amplification factor

A, u & n are constants dependent upon physical construction

To evaluate the constants A, u, n for a VE-124 as used in the Monitron, the plate characteristics were determined experimentally with the tube at potentials identical to that used in the Monitron.

The data shown in Table 1 was obtained. Figure 1 is a plot of this data.

The value of u = 1.2 was obtained from Figure 1 for i_b = 40 microamperes. This value is not constant and the value for u was taken as that between $E_g = -3$ and $E_g = -2$ volts.

Thus the function for the triode would be

$$i_b = A(E_b + 1.2\ E_g)^n$$

To determine the exponent n, the expression $(E_b + 1.2\ E_g)$ is evaluated for various i_b from data of Table 1.

When $E_g = -3$

i_b	E_b	$(E_b + 1.2\ E_g)$
17.8	5.0	5 + 1.2(-3) = 1.4
26.3	5.5	1.9
36.3	6.0	2.4
47.8	6.5	2.9

Then i_b versus $(E_b + 1.2\ E_g)$ was plotted on log-log graph paper. Figure 2. The slope of this line gives the value of the exponent n. This was found to be 1.39.

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The value of A is determined by evaluation of $(E_b + 1.2\ E_g)^{1.39}$

When $E_g = -3$

E_b	$E_b + 1.2\ E_g$	$(E_b + 1.2\ E_g)^n$	i_b	A
5.0	1.4	1.60	17.8	11.1
5.5	1.9	2.44	26.3	10.8
6.0	2.4	3.38	36.3	10.8
6.5	2.9	4.39	47.0	10.9

Thus we find that A is not constant and the value of 11 was arbitrarily chosen. The values of n and A were calculated for different values of E_g. The figures given for $E_g = -3$ serve to illustrate the method used.

We thus find that in the Monitron circuit the characteristics of the V-124 may be represented by the equation $i_b = 11\ (E_b + 1.2\ E_g)^{1.39}$

To check this equation, the values of i_b for different values of E_b and E_g were calculated and plotted on Fig. 1 with x, the dots represent points found experimentally. Thus we find that the above equations are approximately correct.

In Fig. 1, there is drawn a load-line for a load resistance of 75,000 ohms and a plate supply voltage of 8 volts. The equation of this load line is:

$$i_b \text{ (microamperes)} = \frac{E_{bb} - E_b}{R_L} \times 10^6$$

$$i_b = \frac{E_{bb} - E_b}{75{,}000} \times 10^6$$

E_{bb} = plate supply voltage

R_L = load resistance

The tube characteristics are represented by $i_b = 11\ (E_b + 1.2\ E_g)^{1.39}$ and the load line by $i_b = \frac{E_{bb} - E_b}{75} \times 10^3$

Combining these equations:

$$E_b + .825\ (E_b - 1.2\ E_g)^{1.39} = E_{bb}$$

This function is plotted in Figure 3. Modulation depends upon the curvature in these lines which is due to the exponent of the second term in the above equation.

When 2.5 volts AC is added to the plate supply voltage E_{bb}, the maximum value which E_{bb} reaches is $8 + \frac{2.5}{2 \times .707} = 9.77$ and the minimum value 6.23 volts.

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Referring to Fig. 3, when $E_g = -3$ volts, $E_{bb} = 8$ volts, then the voltage on the plate $E_b = 5.68$ volts. When E_{bb} changes to 9.77, E_b becomes 6.38 and when E_{bb} reaches 6.23 volts, $E_b = 4.96$. Thus a variation in E_{bb} of $\pm$ 1.77, produces a variation in E_b of +.70 and -.72 volts. The output voltage, peak to peak is 1.42 volts. When $E_g = -2$, E_b varies by +.63 and -.67. Output voltage from peak to peak is then 1.30. Thus a change of +1 volt in E_g produces a change of 1.42 - 1.30 = .12 volts in AC output. The distortion when $E_g = -3$ is equal to $\frac{.67 - .63}{1.42} = 3\%$.

A summary of the data obtained from Fig. 3 is:

E_{bb}	E_b $E_g = -3$	ΔE_b	E_b when $E_g = -2$	ΔE_b
9.77	6.38	+.70	5.58	+.63
8.00	5.68		4.95	
6.23	4.96	-.72	4.28	-.67

This graphical analysis checks with the results obtained.

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ADDENDUM - CP-3104
addendum

Error correction for last paragraph on page 15 and page 16.

When 2.5 volts AC (rms) is added to the plate supply voltage E_{bb}, the maximum value which E_{bb} reaches is $8 + (2.5 \times 1.414) = 11.54$ and the minimum value 4.46 volts.

Referring to Fig 3, when $E_g = -3$ volts, $E_{bb} = 8$ volts, then the voltage on the plate $E_b = 5.68$ volts. When E_{bb} changes to 11.54, E_b becomes 7.05 and when E_{bb} reaches 4.46 volts, $E_b = 4.15$. Thus a variation in E_{bb} of $\pm$ 3.54 volts, produces a variation in E_b of + 1.37 and - 1.53. The output voltage peak to peak is 2.90 volts. When $E_g = -2$, E_b varies by + 1.30 and - 1.45. Output voltage from peak to peak is then 2.75 volts. Thus a change of + 1 volt in E_g produces a change of $2.90 - 2.75 = .15$ volts in AC peak output. The distortion when $E_g = -3$ is equal to

$$\frac{1.53 - 1.37}{2.90} = \frac{16}{290} = 5.5\%$$

A summary of the data obtained from Fig. 3 is:

E_{bb}	E_b - $E_g = -3$	ΔE_b	E_b when $E_g = -2$	ΔE_b
11.54	7.05	+1.37	6.25	
8.00	5.68		4.95	+1.30
4.46	4.15	-1.53	3.50	-1.45

TABLE

I

E_g (volts)	E_b (volts) 2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5
-1	13.6	23	35	49.5									
-2			12.2	20	30	43.2							
-3						17.8	26.3	36.3	47.8				
-4								16	23.4	33	43.2		
-5										14.5	20.5	28.4	37.2

Body of table is plate current in microamperes.

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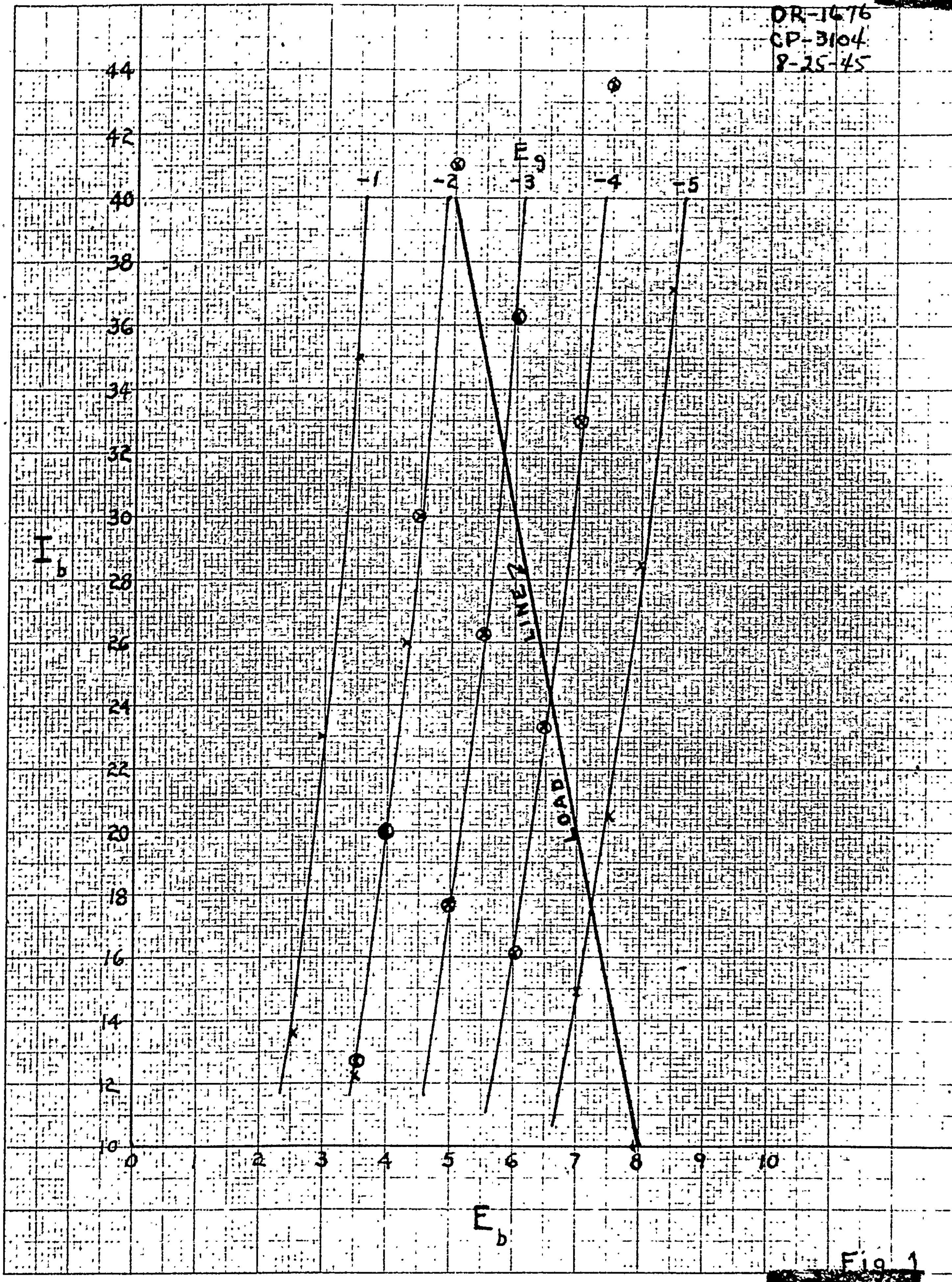

Fig 1

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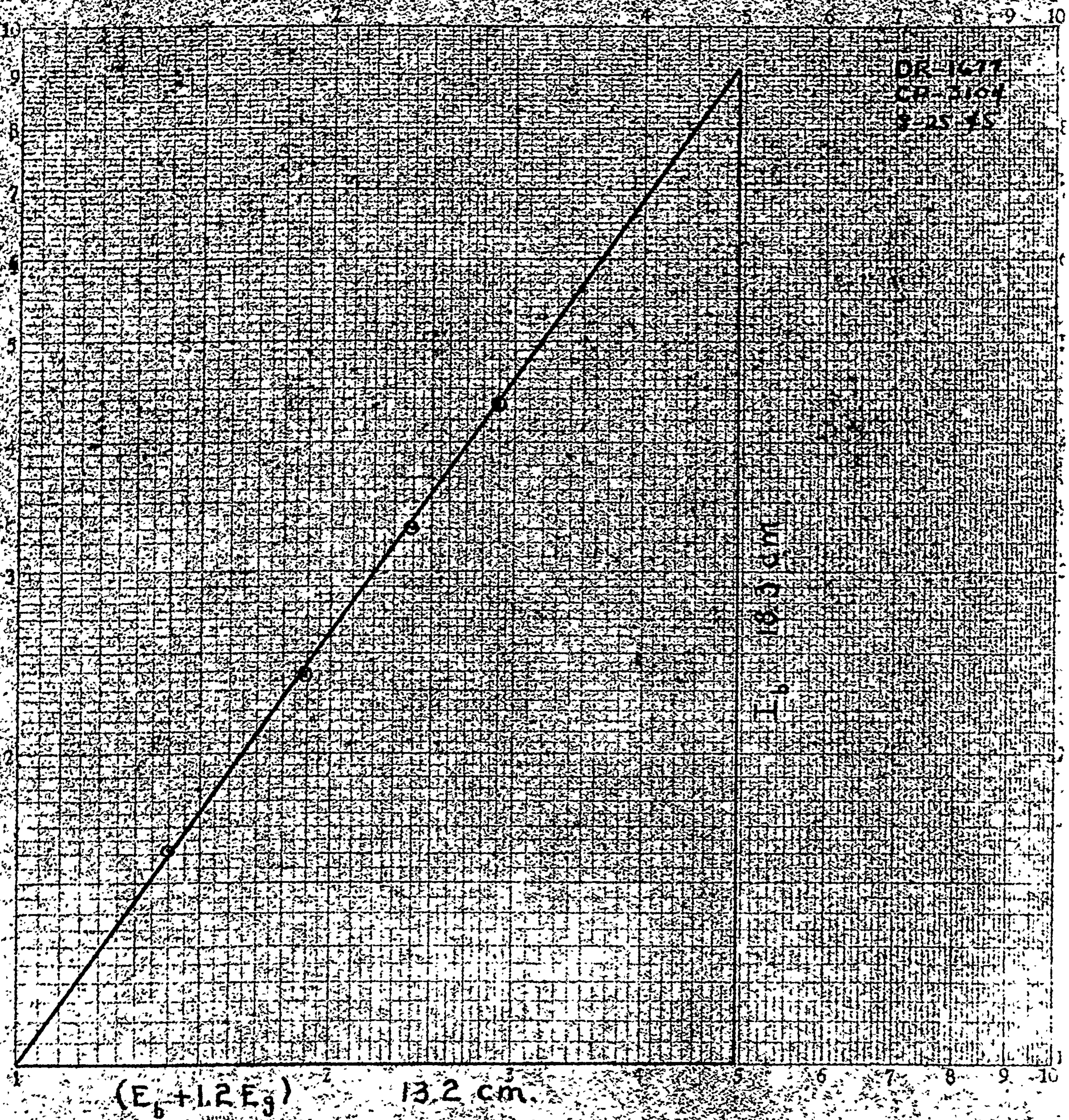

$$\text{SLOPE} = \frac{18.3}{13.2} = 1.39$$

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Fig. #2

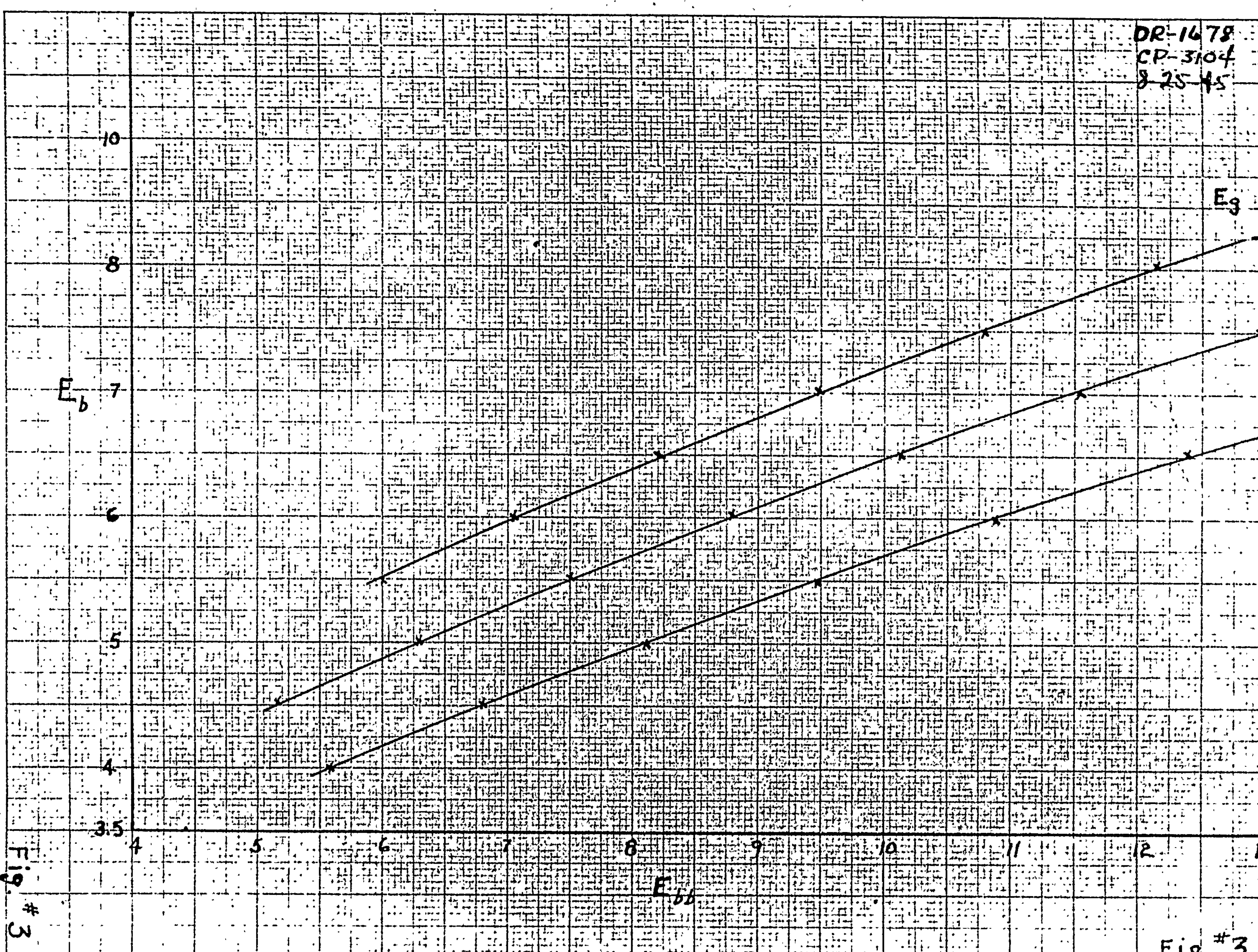
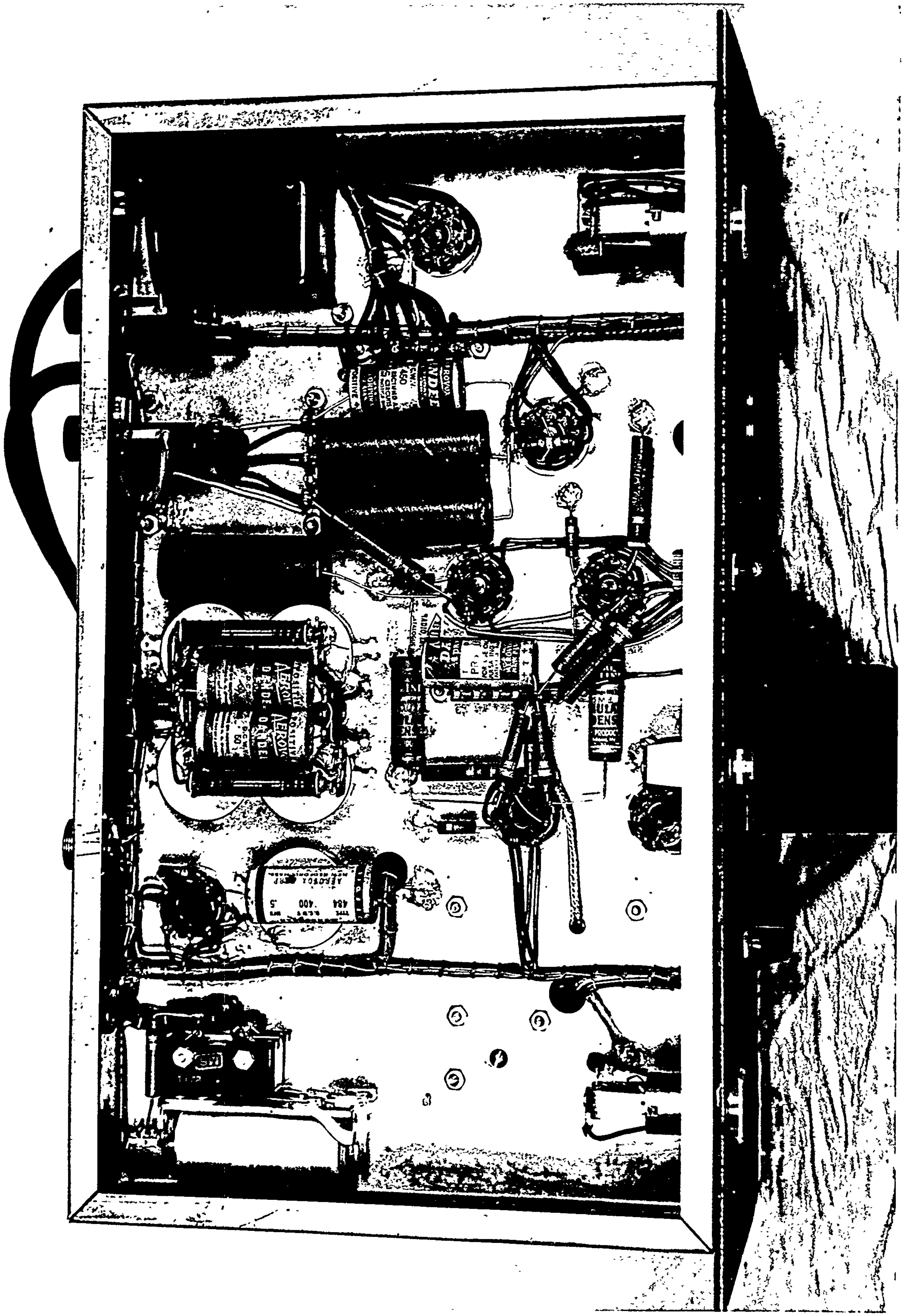
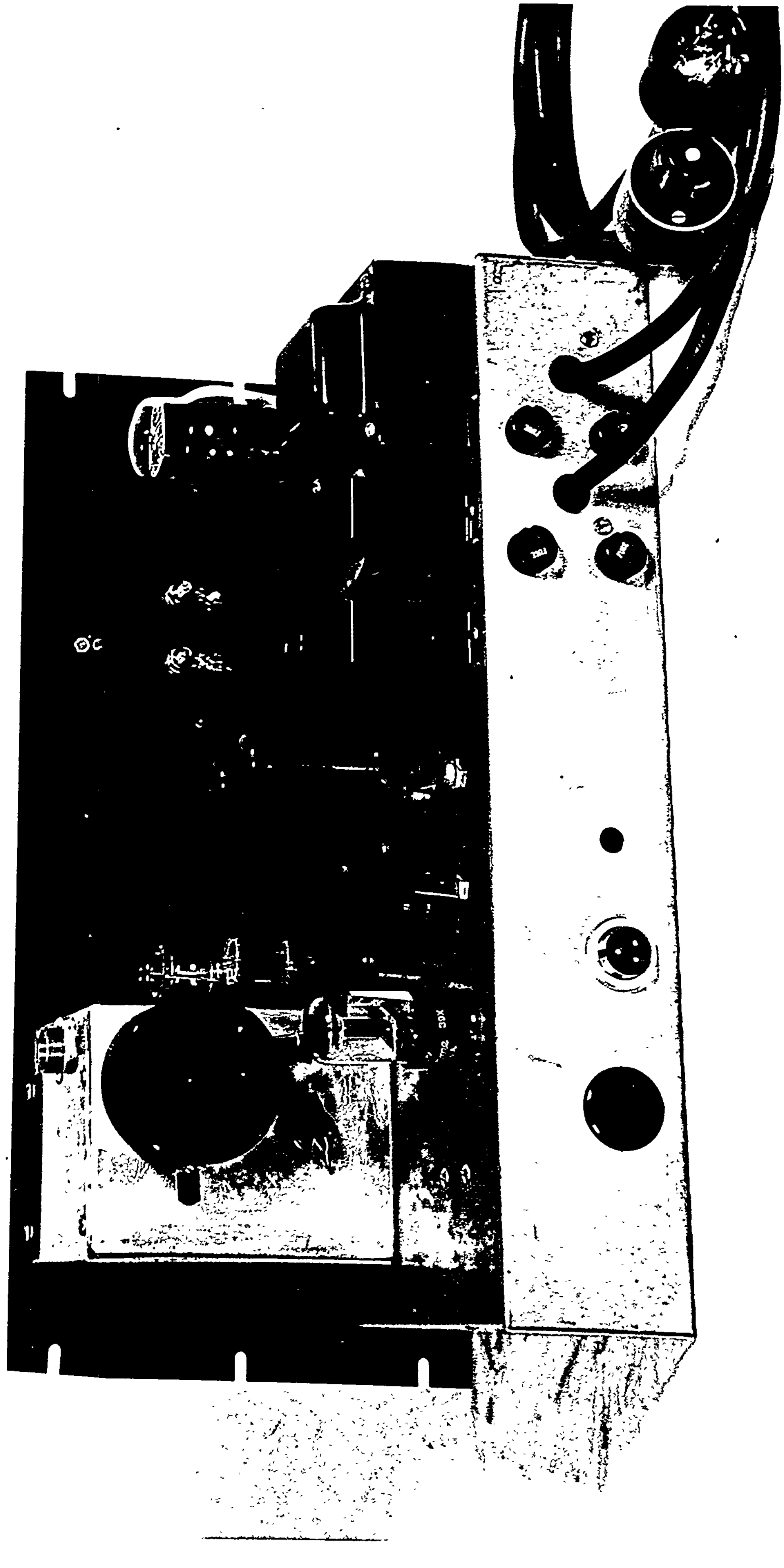
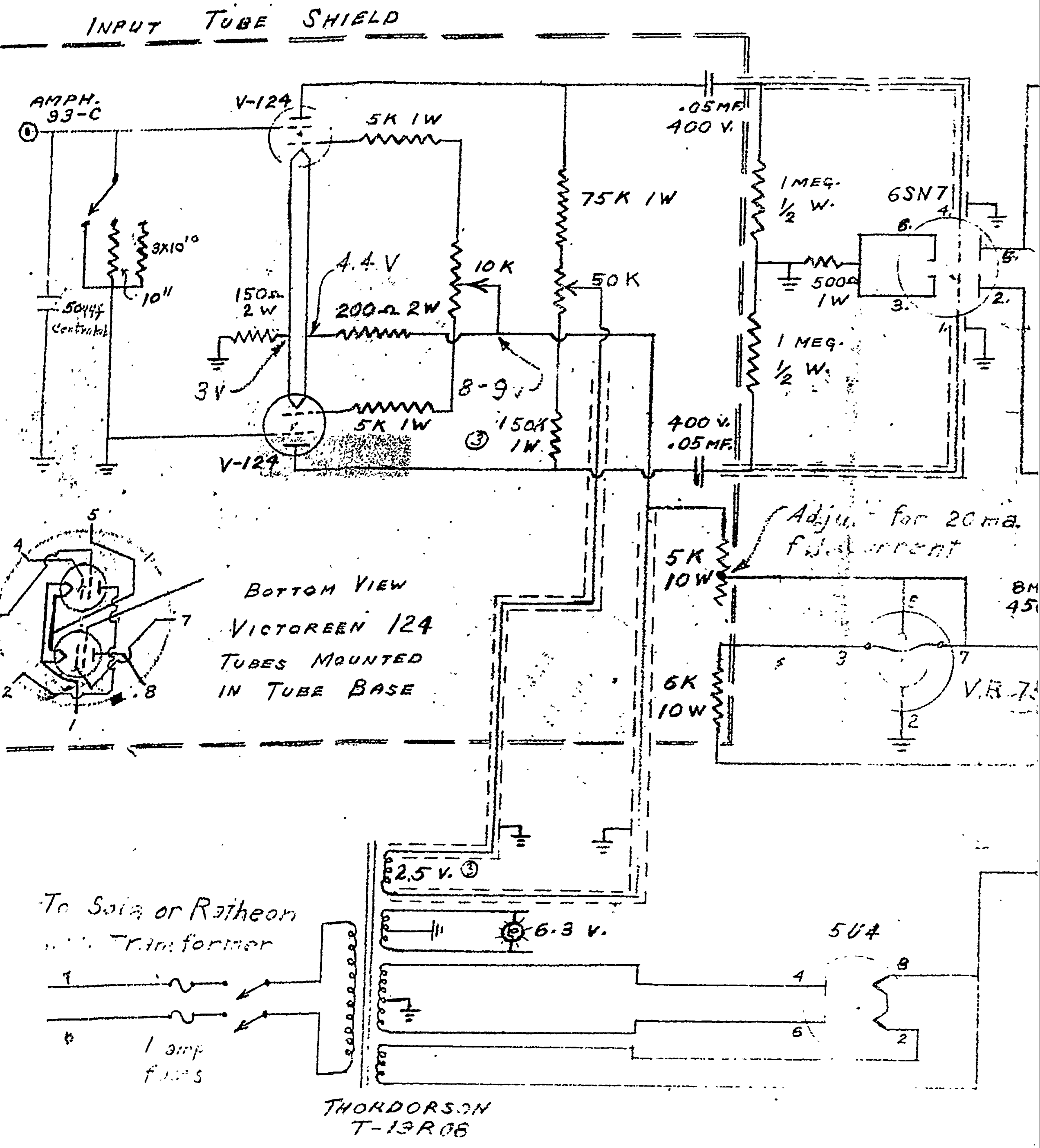


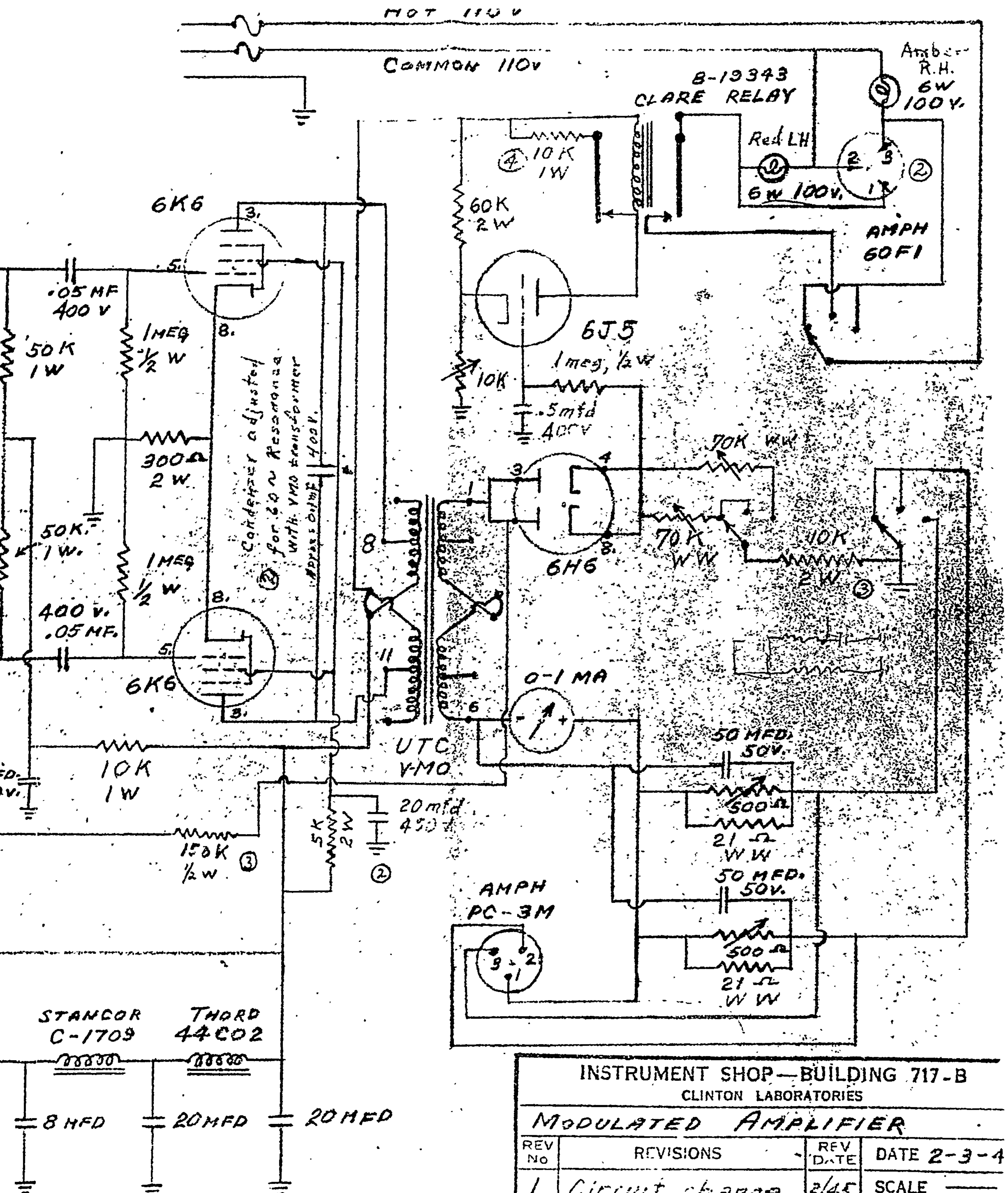
Fig. #3

Fig. #3






INPUT TUBE SHIELD
AMPH. 93-C
V-124
5K 1W
.05 MF 400 V.
1 MEG. 1/2 W.
6SN7
75K 1W
3x10^10
10"
50 μμf Centralab
4.4 V
10 K
50 K
150Ω 2 W
200Ω 2W
5000 1W
1 MEG. 1/2 W.
3 V
8-9 v
150K 1W
400 v. .05 MF.
V-124
Bottom View
Victoreen 124
Tubes Mounted in Tube Base
5K 10W
6K 10W
Adjust for 20 ma. fil. current
V.R.
2.5 v.
6.3 v.
5U4
To Sola or Raytheon Transformer
1 amp fuses
THORDORSON T-13R06



INSTRUMENT SHOP—BUILDING 717-B
CLINTON LABORATORIES

MODULATED AMPLIFIER

REV No	REVISIONS	REV DATE	
			DATE 2-3-4
1	Circuit change	2/45	SCALE ——
2	" "	4/3/45	DRAWN BY [illegible]
3	" "	4/17/45	APP'V'D BY [illegible]
4	" "	6/19/45	BLDG. No.

SKETCH Q-280-A